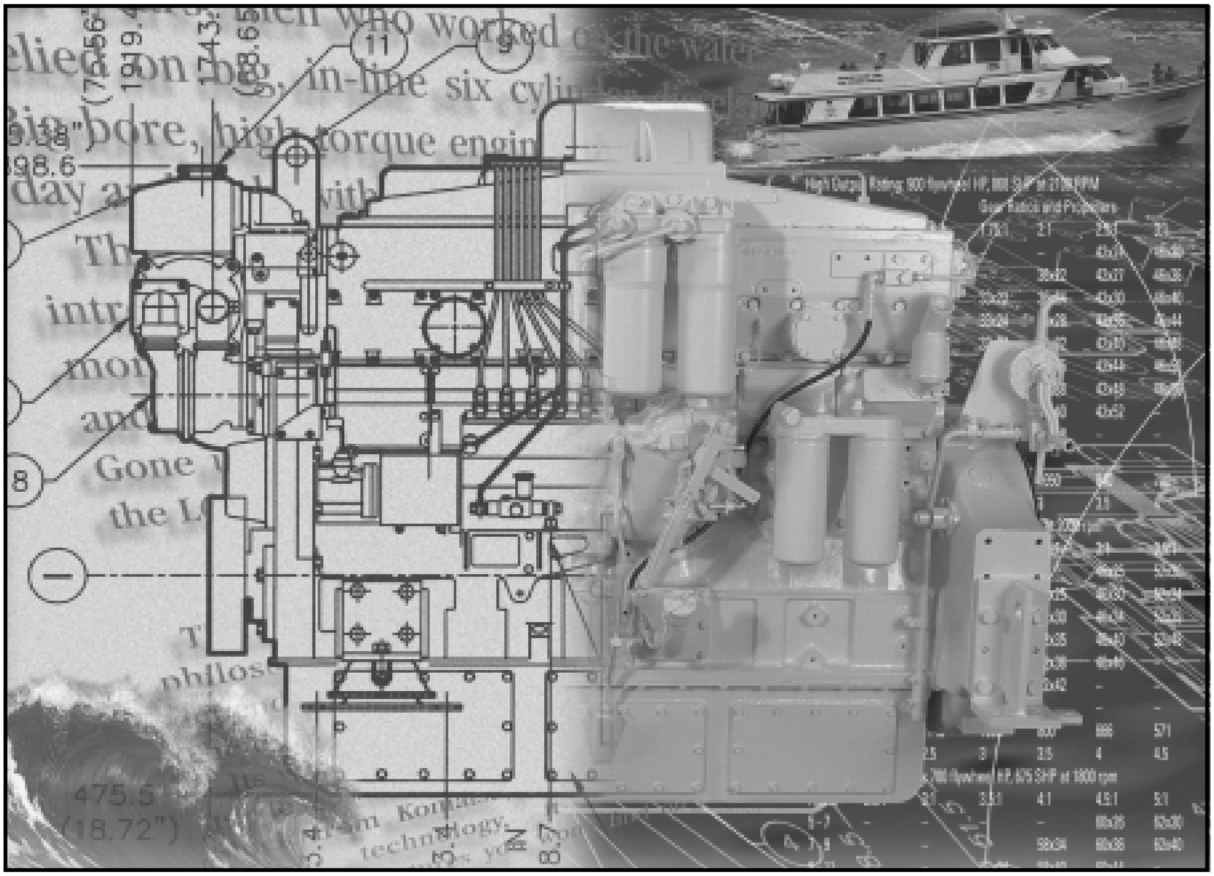


An Introduction To Marine Diesel Propulsion Engines.

NORTHERN LIGHTS
DIESEL ELECTRIC & POWER SYSTEMS

LUGGER®

This document, and more, is available for download at Martin's Marine Engineering Page - www.dieselduck.net

The Choosing, Care and Feeding of Diesels.

An Introduction

You have to love a diesel. They're reliable, efficient and, in the long run, for what they do, aren't all that expensive. Their care and feeding is minimal. If you're planning on purchasing a diesel as a replacement to what you have or with a new vessel, there are some essential, if simple, considerations.

The Diesel

The concept of a diesel is utterly, beautifully simple. Instead of lighting a fire on the stroke of the piston, the simple act of compressing the air and fuel mixture automatically produces combustion. For the user, this means there are fewer things to go wrong, and less danger because the fuel does not combust as easily as gasoline. It also means that the compression of each cylinder has to be good for the diesel to function properly.

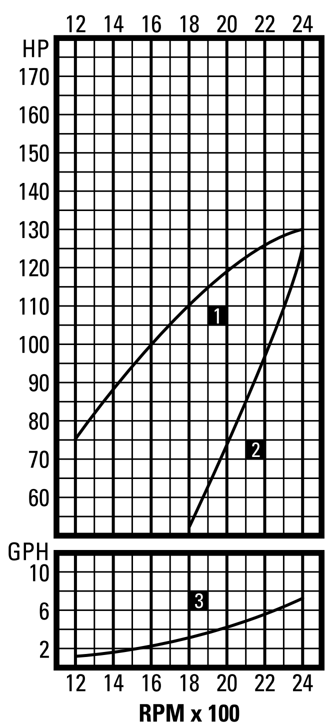


Figure 1: *Power Curves*

Ratings: **High output - 130 @ 2400 rpm, Medium Duty - 117 @ 2400, Continuous Duty - 105 @ 2200 rpm.**

Notes:

1. Max. cruise rpm for High Output and Medium Duty ratings is 200 rpm below highest attainable rpm.
2. Fuel consumption is in U.S. gallons per hour based on High Output theoretical prop shaft horsepower draw. Your fuel consumption will vary higher or lower depending on your vessel and operating conditions.

Curves (Based on High Output ratings) **:**

1. Flywheel power. 2. Theoretical prop power draw (3.0 exponent).
3. Fuel used based on prop power draw.

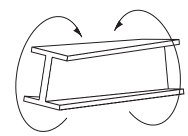
Horsepower

What is a horsepower? Simply put, it is:

$$\frac{\text{33,000 ft. lbs. of work}}{\text{minute}} = \text{1 horsepower}$$

To find out how much horsepower a specific engine has, one has to do some measuring in foot pounds with a dynometer and revolutions per minute (RPMs) of the crankshaft, and then do some calculating.

$$\frac{\text{Torque (ft. lbs). x RPM}}{5252}$$



This last formula shows that horsepower is, of course, partly a function of RPM. Running at high revs ages an engine quickly. While you may be able to get a lot of horsepower out of a relatively small engine by running it fast, the question remains, how long will the engine survive?

Thus comes the rating system. Usually there are three ratings for three different types of work. For Lugger engines they are "continuous duty," "medium duty" and "high output." High output generally applies to planing pleasure boats which aren't expected to push extraordinary loads for long periods and thus can be given the higher rating. There are two specific places to measure horsepower: Brake Horsepower (BHP) is the horsepower at the engine flywheel while Shaft Horsepower (SHP) is the horsepower at the shaft, i.e. after it goes through the transmission/ reduction gear. There is generally a 3-3.5 % loss of horsepower as it goes through the transmission.

Usually comparisons focus on BHP. Make sure you are comparing like figures. The other most fundamental engine number is displacement, or volume of all the engine's cylinders. It is measured in cubic inches or liters. This number is an excellent measure of size and potential power.

The Basic Elements

A diesel's simplicity means that cruisers can, and often do, perform the lion's share of maintenance. At the very least, a basic understanding of the elements and the maintenance of each is important for serious cruisers.

The most important thing to stress here is to keep a maintenance log (*see* ***Figure 2***). Record all maintenance procedures, fuel and oil consumption, plus any significant observations you make about the diesel's operation. This log is well worth the effort, both for sleuthing problems should they arise and also for showing the vessel's next owner what kind of maintenance the engine received.

This document, and more, is available for download at Martin's Marine Engineering Page - www.dieselduck.net

ENGINE LOG
(Keep seperate logs for starboard and port engines)

Date/Time	Eng. Hrs.	Oil Level Eng./Trans.		Water Level	Notes/Visuals/Repairs
4/15/99	3,706.8	1qt	Full	OK	Raw water pump weeping
4/16/99	3,710.2	1½qt	Full	OK	Weeping pump, add oil to injection pump

Figure 2: *Typical Engine Log*

Fuel

Your diesel is only as good as its fuel, and sometimes the fuel from a marina is not as consistent as the gas you buy for your car. There may be sediments, moisture or other impurities that can disrupt a perfectly good injector. A vessel's system for storing and transporting fuel is full of potential problems, such as leaks or corrosion. Leaks are bad, not just because of the fuel that comes out but because of the air that gets in. Air in the fuel lines is one of the few things that will stop a diesel.

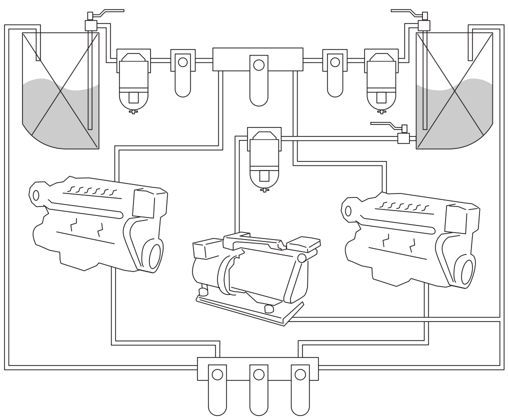


Figure 3: *Fuel System*

Maintenance Tips

- One of the most important considerations is to keep the tanks full, especially during the winter months when condensation can occur.
- Install a high quality filtering system. Forcing fuel to go through even three separate, progressively finer filters is cheap insurance. Moreover, remove the water and sediment from the filter elements at the appropriate intervals.
- Regularly check the injectors and fuel pump for any signs of excessive dirt or leaks.
- If tanks are not kept full during long periods, the water in the tank will enhance the growth rate of diesel fed bacteria. Keeping tanks full will help prevent bacteria contamination.
- Once bacteria have fouled a fuel tank/system, a biocide can be used, but only with great care. Once the biocide is introduced, the bacteria will be killed, allowing their exoskeletons to drop to the bottom of the tank, in line with the fuel intake. It is common for fuel filters to become clogged shortly after biocide introduction.
- If extreme biological contamination is present in the fuel, a fuel polishing service should be considered. These services are available at most larger ports.

Oil

This is the lifeblood of the engine. The condition of the oil in a diesel is absolutely critical to that engine's smooth operation. The condition of the oil is so vital and revealing, in fact, that it can be sent to a lab for analysis. This analysis can often indicate quite clearly the health of an engine or what, if any, problems exist. Oil analysis is most helpful when done over a series of oil changes. This allows the testing service to track changes and trends over time. Sudden increases in certain metals, water or other contaminants can be used to predict and prevent possibly catastrophic damage from occurring. Oil changes should always be entered into the maintenance log. Part of the entry log should be how much oil was burned since the last oil change or the last time oil was added. Some oil will burn, and that is not a bad thing. But if too much oil burns, that raises important red flags.

- Adhere strictly to the oil weight and quality the manufacturer suggests, and the oil and filter change schedule.
- Check the oil daily before heading out.
- Record oil burn and observations about oil condition.

▼ Operation	Service Intervals: Daily	50 Hrs	250 Hrs (2 Weeks)	600 Hrs	1200 Hrs (12 Months)	2000 Hrs (24 Months)
Visual walk-around inspection	✘					
ENGINE						
SP1: Check oil level	✘					
SP2: Change engine oil[1]			✘			
SP3: Change lube oil filter[1]			✘			
SP4: Check (replace) air cleaner[1, 3]			✘	✘		
SP5: Check automatic belt tensioner and belt wear[1]				✘		
SP6: Check & adjust valve clearances[1]				✘	✘	
SP20: Clean crankcase vent tube				✘		
Check crankshaft vibration damper (6-cylinder units only)					✘	
SP21: Adjust droop on generator set engines					✘	
FUEL SYSTEM						
SP7: Check primary filter (Racor)[2]	✘					
SP8: Change primary filter element[2, 3]			✘			
SP9: Change secondary filter[1, 3]				✘		
SP10: Check injectors[1]				✘		
SP11: Check fuel injection pump						✘
TURBOCHARGER						
SP12: Check air lines and oil lines for leakage[1]			✘			

Figure 4: *Typical Maintenance Schedule*

Transmission

A modern marine engine turns too fast for correct propeller sizing. What is needed is a transmission which reduces the engine rpms to the appropriate number of shaft rotations. This "reduction gear" reduces the rotations in a ratio, for example 3:1, where the 3 represents the number of turns an engine makes for each one of the shaft's rotations. This reduction means greater efficiency of the propulsion system. The following procedures are appropriate for general maintenance.

- Check the transmission lubricant regularly.
- Change lubricant at the manufacturer's suggested intervals.
- If so equipped, check the gear oil cooling system for leaks.

This document, and more, is available for download at Martin's Marine Engineering Page - www.dieselduck.net

Air

Assuming that your engine room air supply was properly designed, only regular basic maintenance is required.

Literature on all engines includes the air requirements. If your engine is having otherwise inexplicable problems such as low power or smoke, air supply would be a good place to check.

- Change or clean air filters as recommended.
- Beware of unintentionally impeding the air flow by covering up intake areas. Something as simple as a misplaced plastic bag can stop an engine as quickly as a cut fuel line would.

The engine manufacturer has very specific air availability requirements for a given model. These need to be taken absolutely seriously. Make sure the air intakes and the space itself is adequate for the engine you are considering.

If that supply is inadequate, modifications would have to be made. This becomes particularly important for turbocharged models.

A simple test of engine room air flow: With the engine(s) and generator(s) running at full power, close the engine room door(s) and any windows or other openings which are intended to be closed during normal operation. Run for two minutes in this condition. Open the engine room door, noting any pressure compensation which takes place (on doors that open inward, does the door seem to 'pop' open, or is an outward opening door difficult to open?). Any pressure compensation noted will indicate rarefied air in the engine compartment, requiring increased inflow capacity.

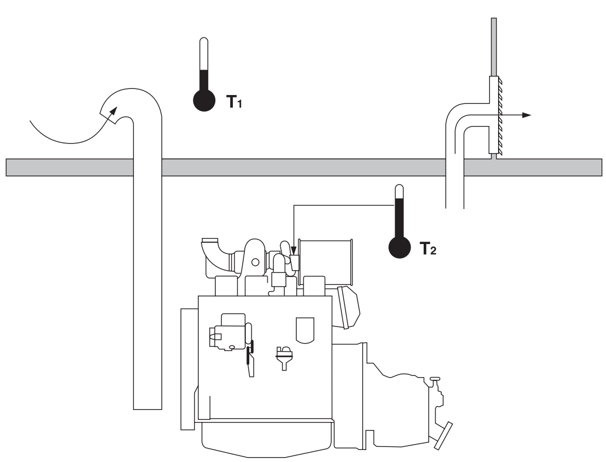


Figure 5: *Air Ventilation System*

Cooling

Your cooling system may be the most problematic part of an engine because it's asked to do a lot. There are two basic kinds of cooling system:

1. Raw water, where water is taken via a through-hull and pumped through the engine and back overboard. Very few of these systems exist on larger, quality engines because of the contaminants (salt in salt water areas!) are pumped into the engine.

2. Fresh water, where an independent, usually treated, fresh water system is all that comes in contact with the engine itself. There are two basic kinds of freshwater systems reflecting two ways of dissipating heat; heat exchanger and keel cooling. In a keel cooling system, the fresh water circuit goes through tubing attached to the outside of the hull and dissipates heat to the surrounding waters.

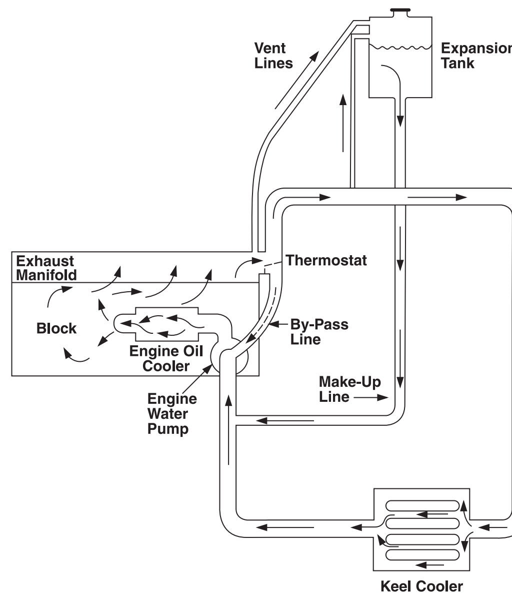


Figure 6: *Keel Cooling System*

In a heat exchanger system, a raw water circuit is pumped via a through-hull into a heat exchanger while the fresh water system also circuits through the heat exchanger. Tubes from both systems are close together and heat is dissipated from the fresh water circuit to the raw water circuit.

Between the heat exchanger and all the plumbing connecting it, there is a lot that can go wrong. In the installation process, all the appropriate engineering should have been followed to the letter. Make notes in the log about the engine operating temperature and particularly if there are changes to that operating temperature.

This document, and more, is available for download at Martin's Marine Engineering Page - www.dieselduck.net

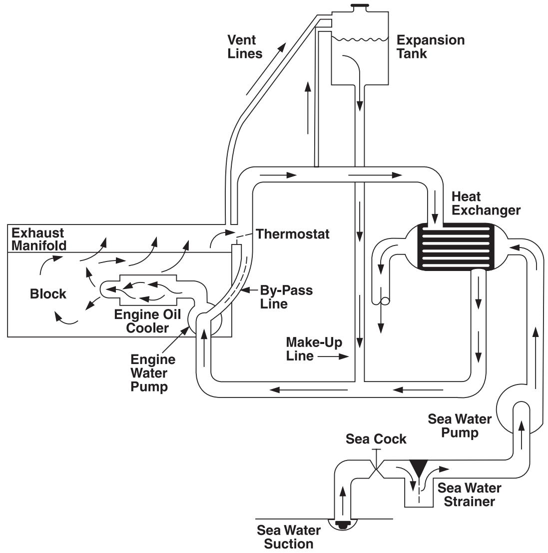


Figure 7: *Heat Exchanger Cooling System*

- Change zinc anodes at recommended intervals.
- Check sea water and raw water pumps and impellers regularly.
- Check and maintain pH balance in coolant.
- Carefully follow manufacturer's recommendations on water-antifreeze coolant mixture and supplemental coolant additives (SCAs) to prevent electrolysis, liner pitting and seal damage.
- Pay close attention to cooling temperature when boat is in water contaminated with floating debris (plastic bags etc.)

Exhaust

The exhaust systems for the engine(s) on your vessel can be extremely varied in design, application and construction. It is imperative that these systems be designed and constructed in such a way as to do the following:

- Provide free exhaust flow to a safe hull exit point, either near the waterline for wet systems, or out the stack for dry systems.
- Care must be taken with dry exhaust systems to protect the boat and operator from hot pipes and their resulting fire hazards.

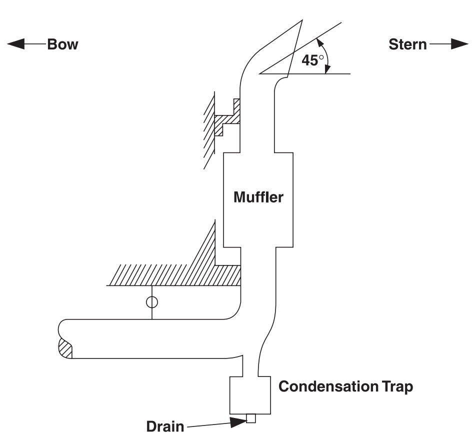


Figure 8: *Dry Exhaust System*

Care must be taken with wet exhaust systems, to assure there is constant flow of cooling water into the system. In the event cooling water is stopped during engine operation, exhaust components will get very hot, damaging hoses and other non-metallic components. The risk of fire is very real under these conditions.

Wet exhaust systems must be carefully designed to eliminate excess backpressure due to standing water in the system. The correct use of water lifts, separators and hose/pipe runs are essential to good design.

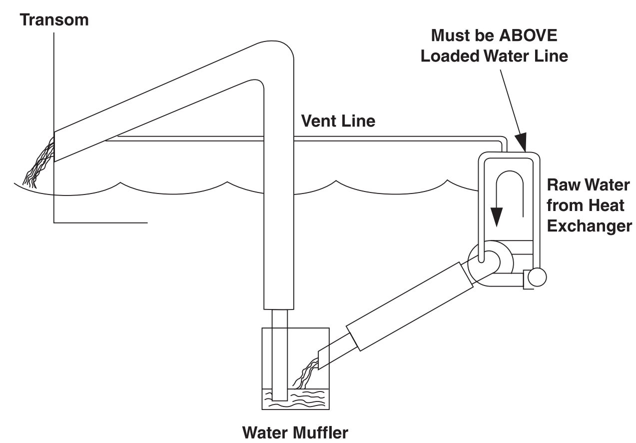


Figure 9: *Wet Exhaust System*

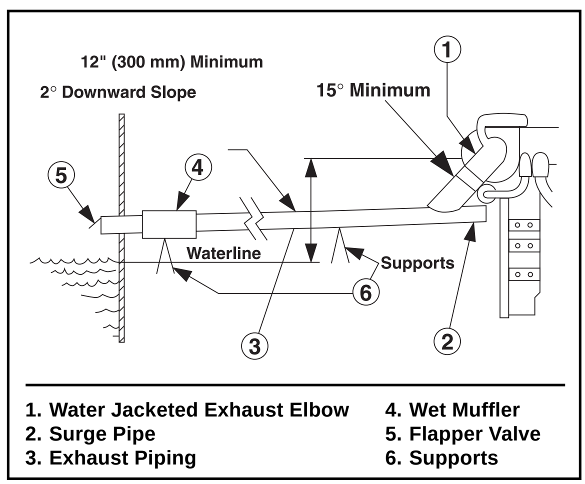


Figure 10: *Wet Exhaust In-line Injection System*

Exhaust pipe/hose sizing is critical to both wet and dry designs. Pipe or hose that is too small will produce excessive backpressure. Systems that use oversize pipes or hoses can suffer from exhaust velocities which are too low, causing soot accumulation. Standing water collection in wet exhaust systems is common when oversized exhaust hose is used.

Contact your engine supplier for correct exhaust system design and backpressure limits for the engine(s) you are using.

This document, and more, is available for download at Martin's Marine Engineering Page - www.dieselduck.net

Choosing a Repower Engine.

The decision to repower does not come easily. Should an existing engine be rebuilt instead? What HP do I want/need? Who makes the best engine for my boat? A few basic answers might help clarify the issue and whittle down the possibilities.

What fits?

The engine sits on stringers that are built into the hull. These are made to match the engine's "footprint." While not always easy, these stringers can often be redone to match a new footprint in the case of a repower. If you can get an engine to sit on the same stringers, that may be a very important consideration. Building new stringers can be expensive and problematic. Another option for fitting an engine is utilizing a down-angle reduction gear to lower the engine's profile. The length of an engine is critical as well. A new shaft may be required, or a shaft may have to be cut, to position the propeller in the correct place with new engine.

What horsepower do I want?

When your boat was designed, the naval architect had an idea of how fast it would go. For many trawlers, this is a function of waterline length. Semi-planing and planing yachts are capable of going significantly faster, depending on displacement and other factors. The question boils down to, "how fast can your boat reasonably go and what horsepower (with an appropriate amount of reserve power) will be required to achieve that speed."

Once the potential speed has been established, then comes the science (some call it art) of wedding an engine and a marine reduction gear to a propeller. Knowing the approximate speed of the vessel, a table of prop sizes and reduction ratios can be used to come up with the best combination. Use the chart below as an example.

As precise as this might seem, it is still trial and error that will determine the exact propeller size that will allow the engine to turn at its maximum rated rpms while the vessel is delivering the performance expected. There may be some limitations such as propeller clearance under the hull (there should be at least 10% of propeller's diameter open between the hull and the propeller blade tip). Another potential limitation is the marine gear location. This has to be able to connect with a coupler to the shaft.

Even when the engine, gear and props are all determined properly, matching all these to the boat is trial and error. With a WOT (wide open throttle), and the vessel loaded with tanks and gear, the engine should be turning its maximum rated rpms. If not, adjustments to the diameter or pitch of the prop are usually in order.

Shaft Size, Propeller diameter and pitch, Marine reduction gear:

It's important to go through the exercise of determining the reduction gear, propeller size and shaft size that would work with a given engine in your boat. Sometimes the gear you require might not fit in your boat, or a larger propeller is required than will fit under your hull. Once again, this will whittle the options to what's truly feasible.

Power	**13 - 15 knots**	**12 - 14 knots**	**10 - 13 knots**	**8 - 10 knots**	
Gear Ratio	**2:1**	**2.5:1**	**3:1**	**3.8:1**	**4.5:1**
80 HP / 2500 Max RPM	20 x 15 1250	23 x 18 1000	26 x 20 833	—	—
110 HP / 2500 Max RPM	21 x 16 1250	24 x 18 1000	26 x 23 833	—	—
130 HP / 2400 Max RPM	23 x 18 1200	26 x 24 960	30 x 25 800	34 x 27 631	38 x 36 533
175 HP / 2400 Max RPM	24 x 23 1200	28 x 27 960	31 x 28 800	35 x 29 631	38 x 38 533

Figure 11: *Three Bladed Propeller Sizing Recommendations*

1. Use this chart to find the **approximate, three bladed** propeller size for your vessel. Use this chart as a guideline only. Contact factory for actual propeller recommendation for your vessel and for medium and continuous duty propeller sizes.
2. In the left column find the engine, then find the boat speed your builder expects from an engine of this HP on the top line. Locate the point where the two columns intersect for propeller size and shaft rpm.

Example:
175 HP model in a 12 kt boat uses 1:1 gear ratio and turns a 24 x 23 prop 1200 rpm.

This document, and more, is available for download at Martin's Marine Engineering Page - www.dieselduck.net

What about my electricity?

If your existing engine requires 12-volt and your new system requires 12-volt, nothing may be required. Of course if you're switching from 24-volt to 12-volt, the electrical system must be changed accordingly. But if you want to do any major work on the electrical system, from rewiring to installing a generator system, the right time may be when the main engine(s) are out of the boat. There's more room to work and it means that work and the repowering can be done at the same time.

Are my fuel tanks still good?

If you are switching from gas to diesel, the tanks and the tubing – including fuel return lines – will have to be installed new. Note that galvanized tanks should not be used for diesel. If you are switching engines, it is a good time to check if there are any causes for concern such as sediment in the tanks or weakened or substandard fuel lines.

If you are repowering from gas to diesel, new tanks will be necessary to ensure your new engine runs on the right fuel from the outset. Proper placement of tanks is an important part in keeping your vessel in trim. Foresight in fuel filter location will make it more (or less) likely that the maintenance gets done, but it's also not a good idea to force the fuel along a convoluted route to the engine.

Each engine on board should have its own, dedicated fuel supply and return system. Combining fuel systems can lead to poor performance or engine damage.

You rely on your power to get you to the next port safely and on time. Diesel engines have been refined to an amazing degree, and there is little fault to be found in today's machinery. The only thing that's required is a basic understanding and some regular maintenance.

If a repower is in your future, install several options on paper first. It will become clear what's possible, what's desirable and what to expect in terms of cost and results. Time spent here will be amply rewarded with a reliable installation that will be good for years to come.

***Note:** This publication is an introduction to diesels only. Always consult the manufacturer's model-specific literature when choosing, installing or maintaining an engine.*

This document, and more, is available for download at Martin's Marine Engineering Page - www.dieselduck.net